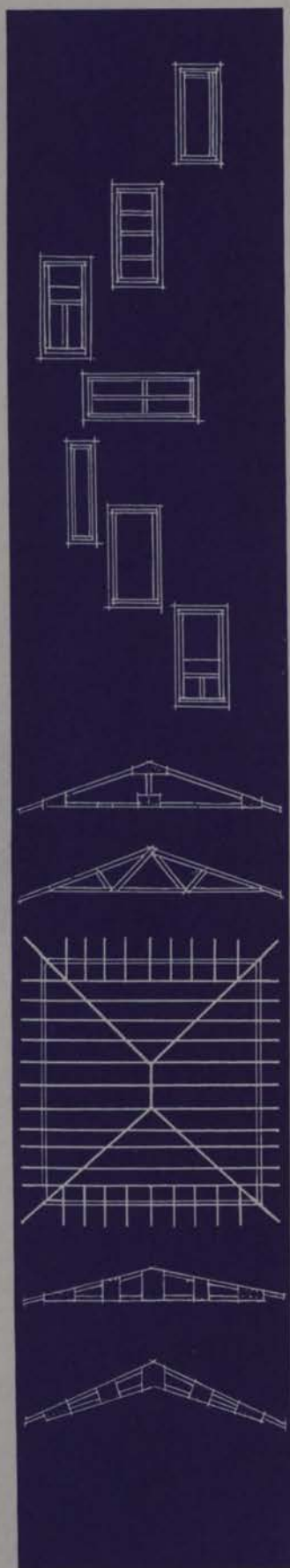

TIME AND COST STUDIES ON FIVE FLOOR SYSTEMS

Rudard A. Jones

Donald H. Percival

Research Report 63-2

UNIVERSITY OF ILLINOIS
SMALL HOMES COUNCIL–
BUILDING RESEARCH COUNCIL

TIME AND COST STUDIES

ON FIVE FLOOR SYSTEMS

Research Report 63-2

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A. I. A.

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Wood Technologist

October 1963

This publication is a report of a time study performed by the University of Illinois Small Homes Council - Building Research Council pursuant to an agreement for cooperative investigation between the University and the Lumber Dealers Research Council. The Weyerhaeuser Company cooperated with the Lumber Dealers Research Council in the sponsorship of this project.

Price: $1.50

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ABSTRACT

The fabrication and construction of five floor framing and subflooring systems was observed and records were kept of the labor times and materials costs of these systems, which were designed for use of 25/32" strip finish flooring.

The following conclusions are valid only for systems in which 25/32" strip flooring is used as the finish flooring:

Framing

1. 2 x 10 joists spaced 24 inches on center were less costly than 2 x 8 joists spaced 16 inches on center.
2. Systems with joists butted over the center girder and tied together with the plywood subfloor were less costly than comparable systems with a lap joint at the center.

Subflooring

1. The 1/2" plywood subfloor resulted in both the lowest material and labor cost for subflooring. The combined material and labor cost was substantially lower than that of any of the other subflooring materials.
2. The savings (reduced labor and reduced waste) gained by installing 1 x 6 T & G end-matched subflooring did not offset the added cost of this material as compared to 1 x 6 S4S boards.

System

1. The overall cost of systems employing 1/2" plywood subflooring over conventional joist floor framing was substantially lower than the component system or systems using other subflooring materials. This statement is true without regard to the type of center joint--butted or lapped.
2. The component system had the highest labor cost and highest total cost although the material cost was somewhat less than the system for which 1 x 6 T & G subflooring was used.

I. INTRODUCTION

This report is a presentation and discussion of information obtained in a time and cost study of five floor systems. The study was carried out as part of an agreement between the Lumber Dealers Research Council and the University of Illinois Small Homes Council-Building Research Council for a cooperative investigation in Residential Construction.

Under the conditions of the agreement, the SHC-BRC was to perform the time and cost study at a site designated by the Lumber Dealers Research Council.

In June 1963, the sponsor was successful in making arrangements, through the Everett Lumber Company of Fort Collins, Colorado, for a builder, Mr. William Leichliter, of Longmont, Colorado, to build five floor systems. The framing operation was subcontracted to Mr. M. J. Simmons, owner of the Mountain View Construction Company, Boulder, Colorado.

The Union Manufacturing Company, owned and managed by the Everett Lumber Company, Fort Collins, Colorado, furnished all of the materials and precut and fabricated certain parts for this study.

In the plan of operations it was agreed that the builder would follow the procedure and details he normally used, with two exceptions: (1) the systems, other than the component system, should meet the Minimum Property Standards of the Federal Housing Administration; (2) all materials, excepting the board subflooring and the tongue and groove subflooring, would be precut and prefabricated.

It was also recognized that the systems would have to comply with local regulations.

The Small Homes Council-Building Research Council agreed to prepare detailed framing and subflooring plans for each system and to collect time, material and cost data on the five floor systems.

II. TEST HOUSES AND SYSTEMS

House

The house chosen for the five systems was a crawl-space house with the dimensions of 24'-0" x 38'-0 3/4". A foundation for an attached single-car garage was also included in the five houses.

Finish Flooring

The builder stipulated that 25/32" oak strip flooring would be used as finish flooring in the five houses. Where this flooring is used, the FHA Minimum Property Standards allow wider joist spacing, and thinner plywood subflooring. Also, no blocking is required under plywood edges. The framing and subflooring combinations used in this study are not necessarily suitable for other thicknesses and/or types of flooring.

Framing and Subfloor Systems

The Lumber Dealers Research Council and the SHC-BRC had previously selected five systems for study. Some minor modifications to the systems were made in order that the builder might follow his current practice as nearly as possible; other modifications were made to meet local codes or FHA Minimum Property Standards, although the houses were not to be insured by the FHA.

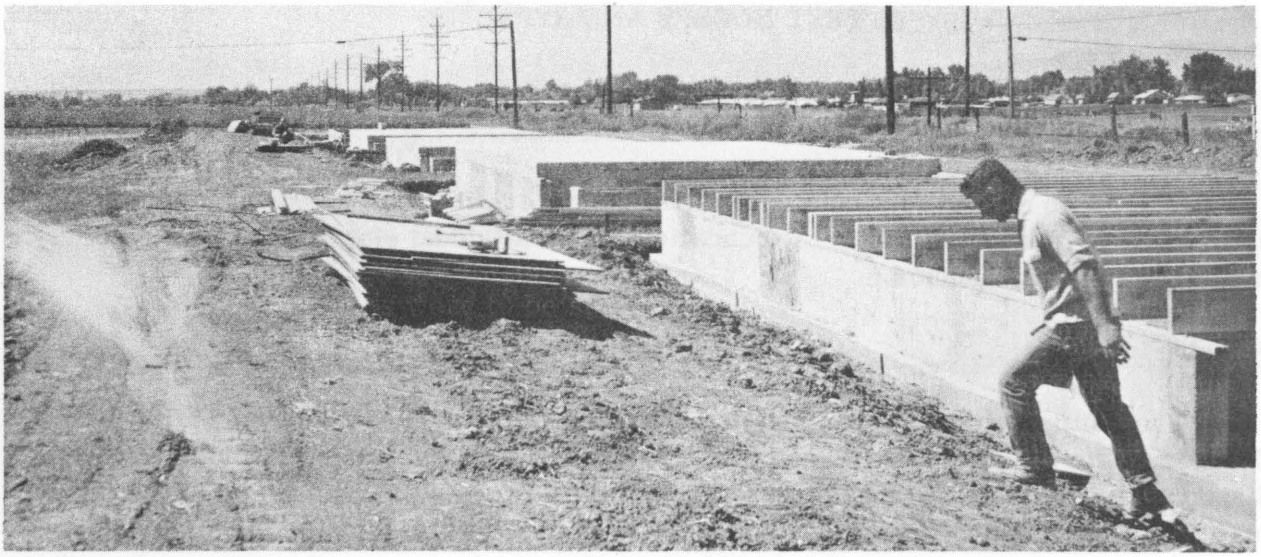
The selected systems are illustrated on the following pages and are specified as follows:

System #1, to be 2 x 8 floor joists, 16" o.c., one foot lap over the center girder, 1 x 4 bridging, and decking of 1 x 6, S4S board placed diagonally. 1 x 8 headers (band joists) were to be used along the long dimensions of the structure in accordance with the builder's practice.

System #2, to be 2 x 8 floor joists, 16" o.c., butted over the girder, 1 x 4 bridging, and a subfloor of 1/2" plywood positioned to offer continuous tie over the center joint of the joists. 1 x 8 headers were to be employed.

System #3, to be constructed using 2 x 10 joists, 24" o.c., one foot lap over the center girder, 1 x 4 bridging, and 1 x 6 tongue and grooved and end matched* subfloor applied diagonally. 1 x 10 headers were to be used on the long sides of the house.

*The material supplier was unable to supply end-matched material at the time of construction; however, the square-end 1 x 6 was installed as though it were end-matched.



Site of test houses

System #4, to be constructed of 2 x 10 joists, 24" o.c., butted over the girder, 1 x 4 bridging and 1/2" plywood subfloor positioned to offer continuous tie over the center joint of the joists. 1 x 10 headers were to be used on the sides.

System #5, to be a component system[#] with beams of double 2 x 10 sections with a 2 x 4* ledger strip nailed to each side of each beam. The beams were to be spaced 4 feet on center, and with 4 x 8 panels and made to support with half-inch plywood stapled to 2 x 4 ribs spaced 24" o.c. Headers were to be 2 x 10 members.

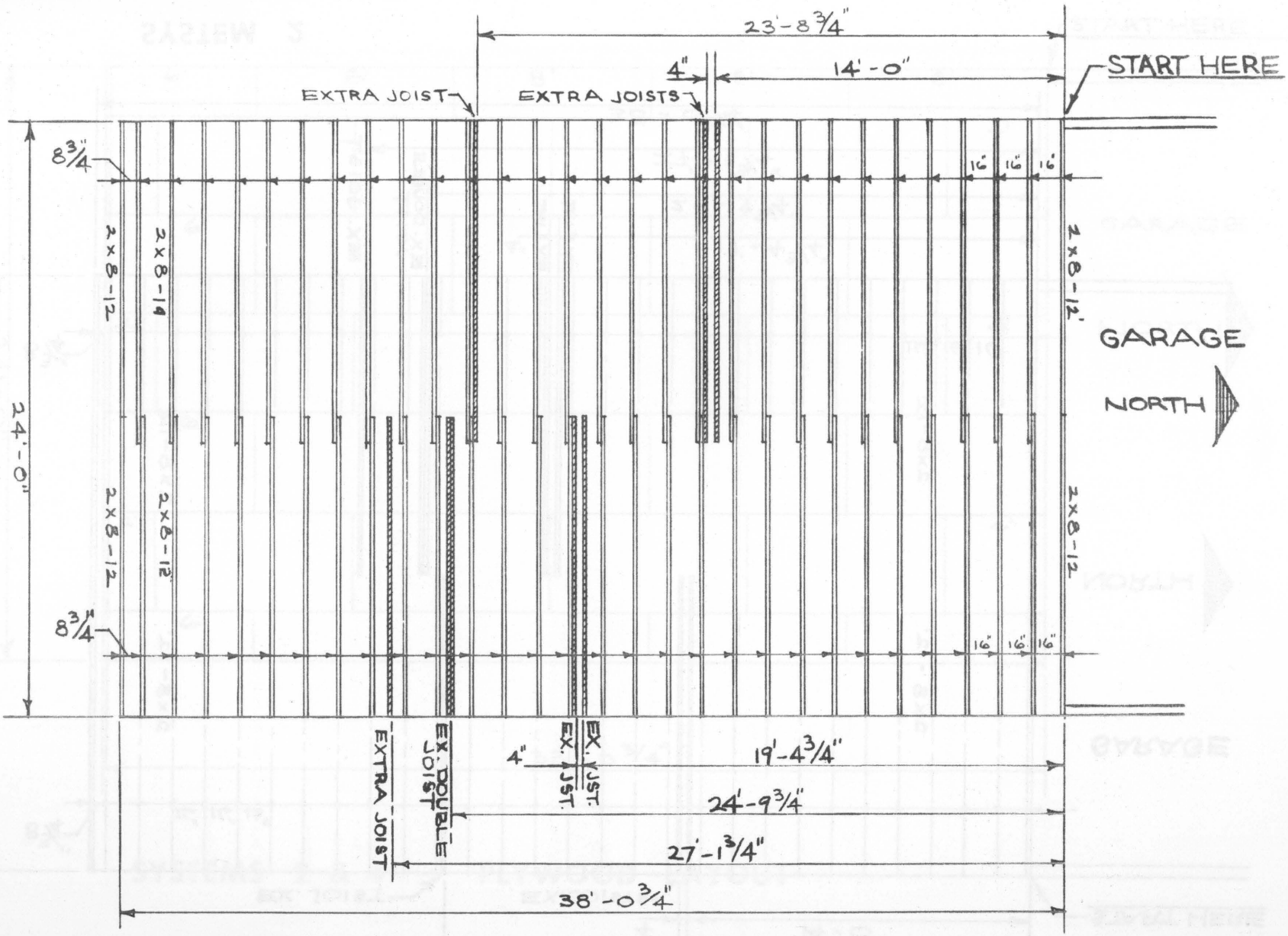
In systems 1, 2, 3, and 4, 1 x 4 bridging was to be used, as required by local codes. The bridging was to be nailed midway between the center girder and the outside wall on each side.

Extra joists and doubled joists under parallel partitions were to be used in accordance with FHA Minimum Property Standards. This was not in accordance with the builder's standard operation.

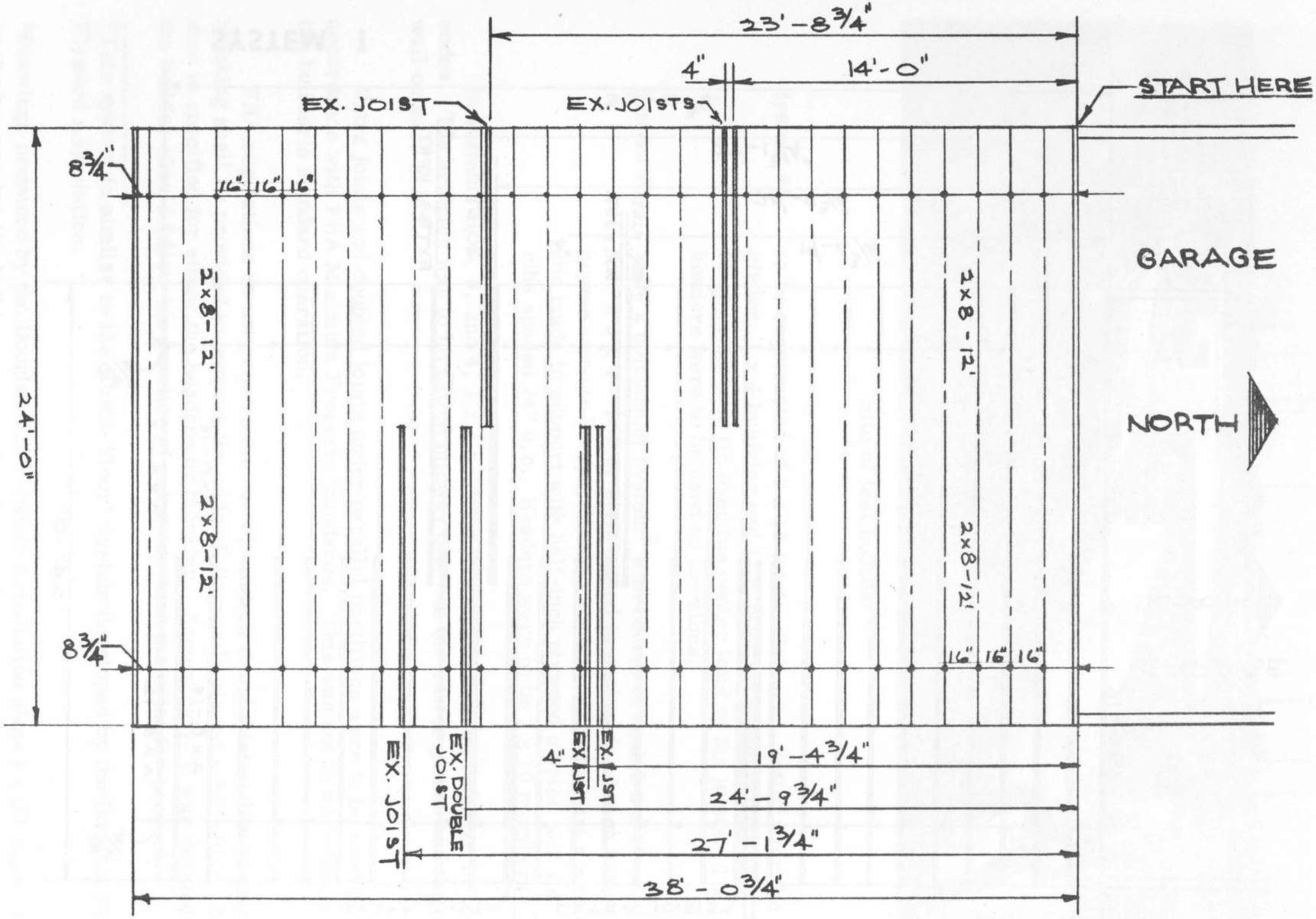
FHA regulations do not require the use of headers (band joists), but do specify blocking shall be provided to support the ends of diagonally placed subflooring. No size is specified for either the headers or blocking. Accordingly, it was decided the builder should follow his practice of using one-inch material for headers.

[#]This system is similar to the "Insta-Floor" System developed by the Douglas Fir Plywood Association.

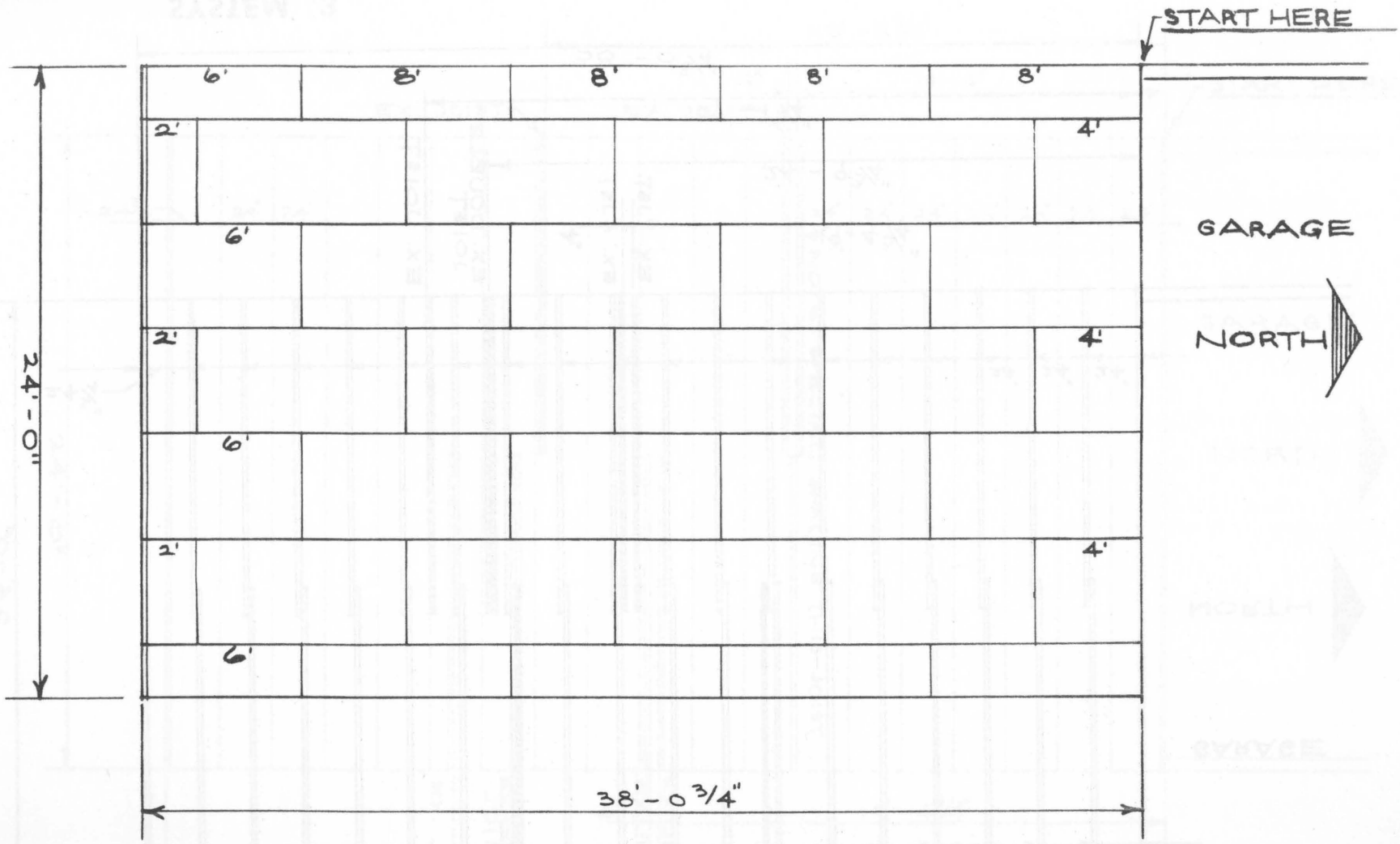
*Drawings prepared by the Douglas Fir Plywood Association show 1 x 2 ledger strips on the beams, but the builder requested that 2 x 4 ledgers be used.


23'-8 3/4"
4"
14'-0"
START HERE
EXTRA JOIST
EXTRA JOISTS
8 3/4"
2x8-12
2x8-14
2x8-12
2x8-12
2x8-12
16"
16"
16"
16"
16"
16"
24'-0"
8 3/4"
GARAGE
NORTH
EXTRA JOIST
EX. DOUBLE JOIST
4"
EX. JST.
EX. JST.
19'-4 3/4"
24'-9 3/4"
27'-1 3/4"
38'-0 3/4"

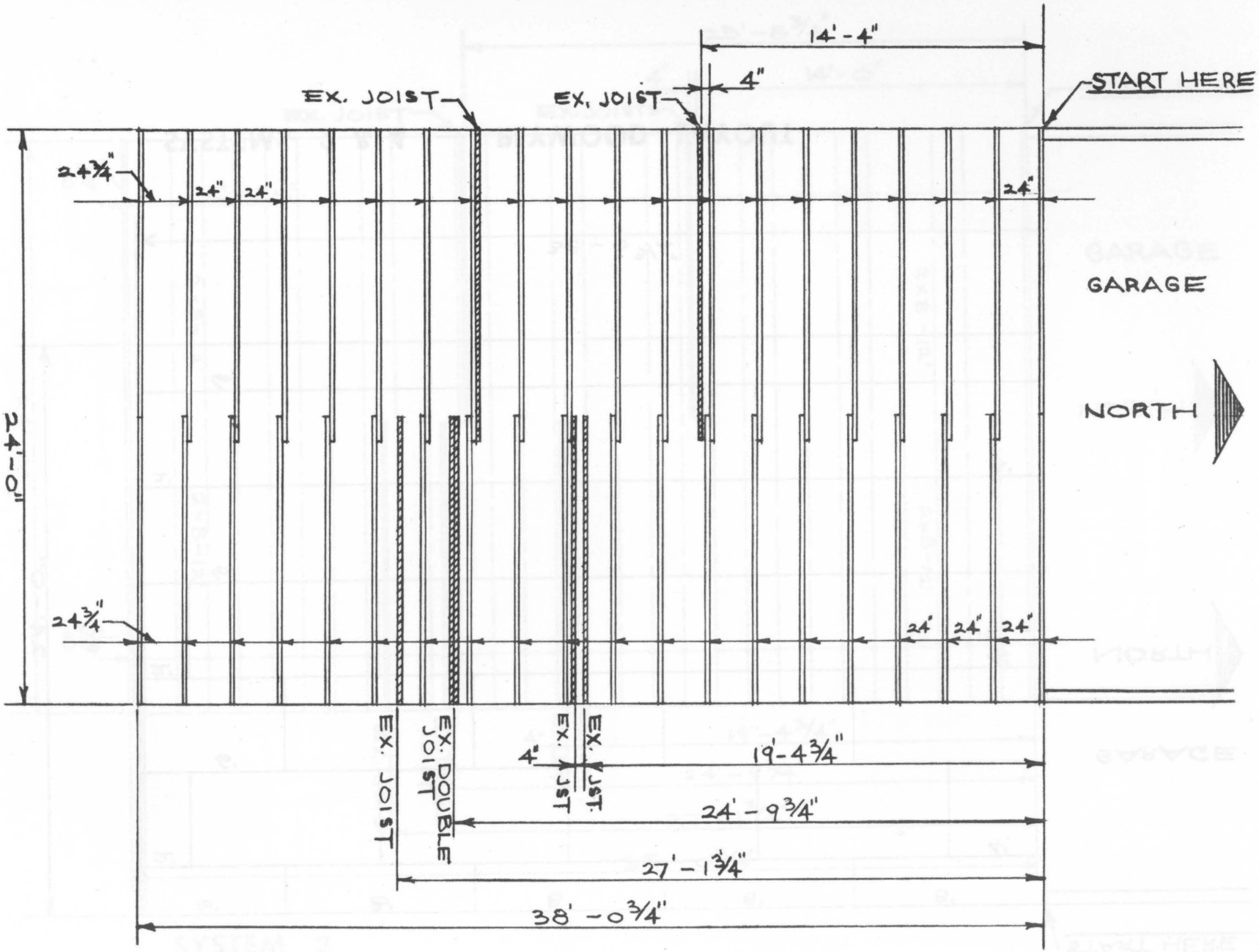
SYSTEM 1


23'-8 3/4"
4"
14'-0"
START HERE
EX. JOIST
EX. JOISTS
8 3/4"
16" 16" 16"
2x8-12'
2x8-12'
2x8-12'
2x8-12'
GARAGE
NORTH
24'-0"
8 3/4"
16" 16" 16"
EX. JOIST
EX. DOUBLE JOIST
4"
EX. 1ST
EX. 1ST
19'-4 3/4"
24'-9 3/4"
27'-1 3/4"
38'-0 3/4"

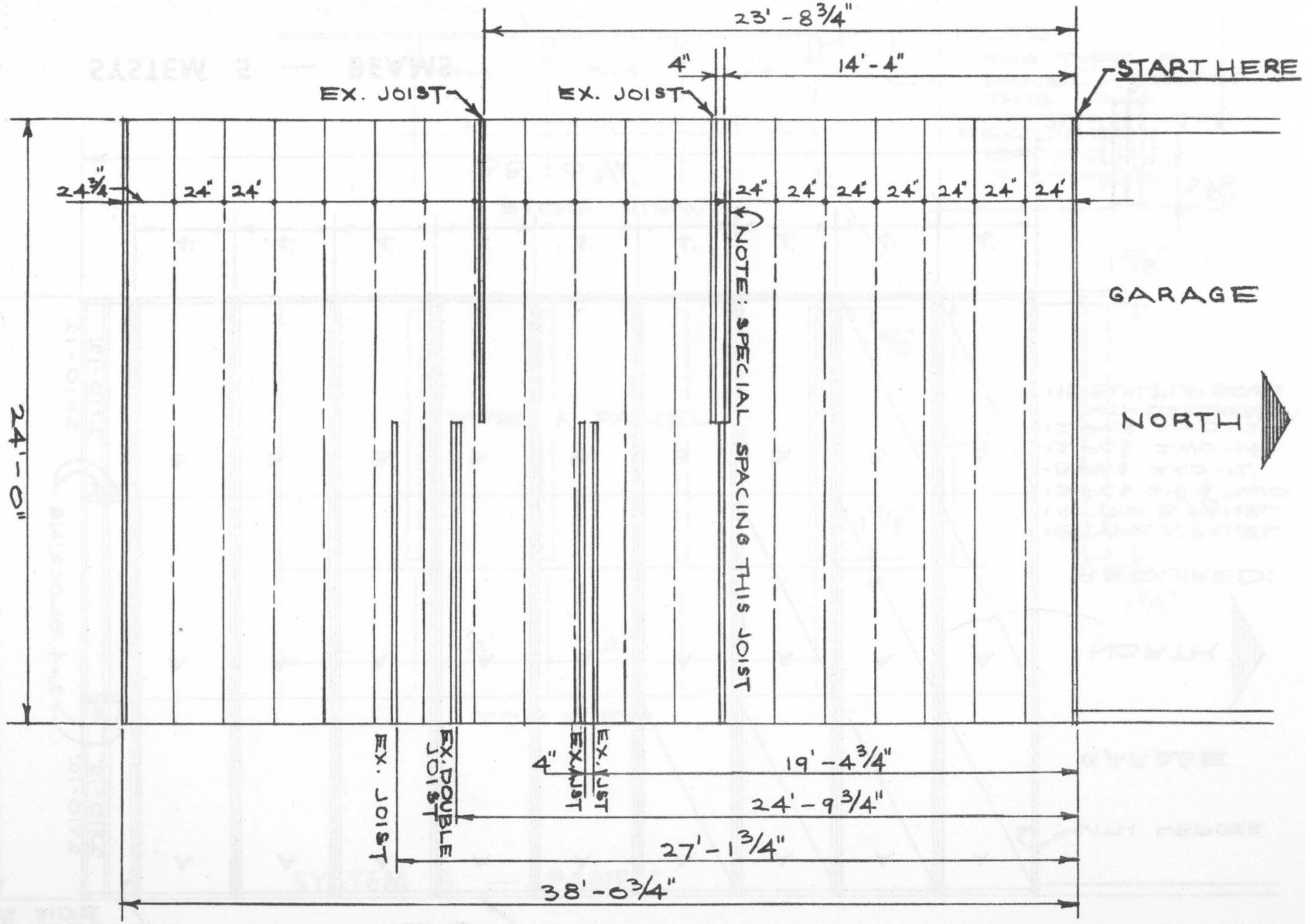
SYSTEM 2



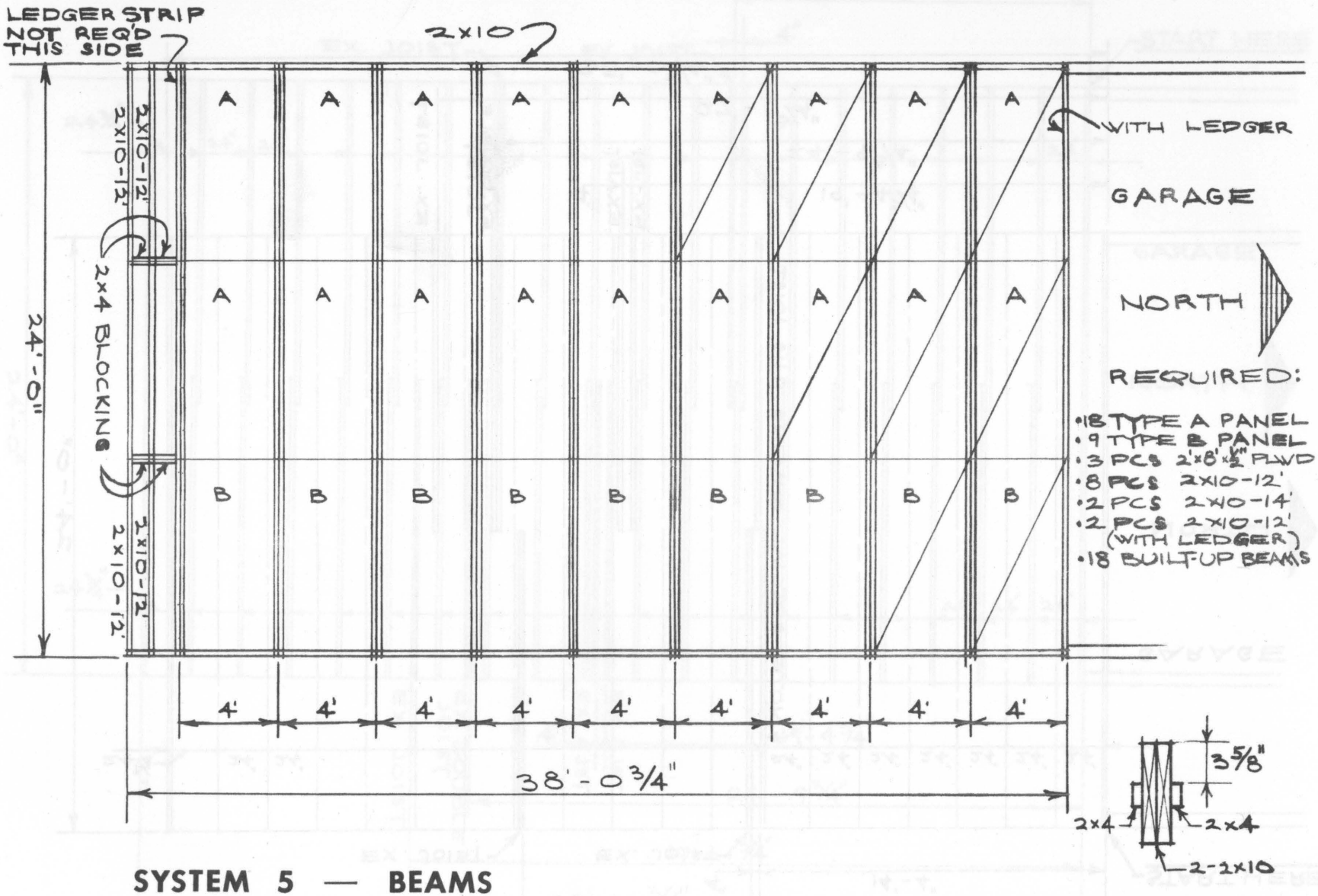
SYSTEMS 2 & 4 — PLYWOOD LAYOUT


14'-4"
4"
START HERE
EX. JOIST
EX. JOIST
24¾"
24"
24"
24"
GARAGE
NORTH
24'-0"
24¾"
24"
24"
24"
EX. JOIST
EX. DOUBLE JOIST
4"
EX. JST.
EX. JST.
19'-4¾"
24'-9¾"
27'-1¾"
38'-0¾"

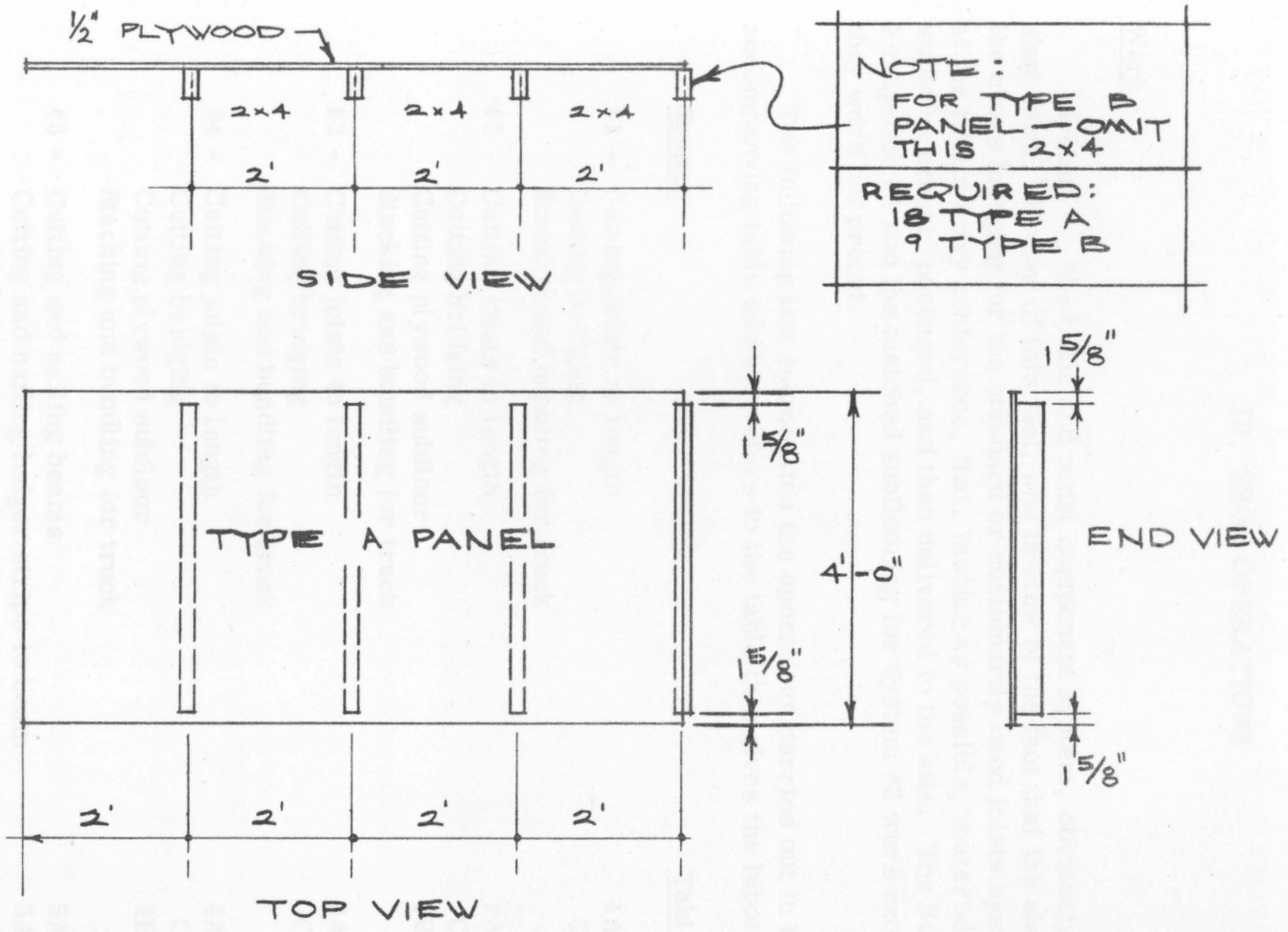
SYSTEM 3


23' - 8 3/4"
4"
14' - 4"
START HERE
EX. JOIST
EX. JOIST
24 3/4"
24"
24"
24"
24"
24"
24"
24"
24"
24"
24"
24"
NOTE: SPECIAL SPACING THIS JOIST
GARAGE
NORTH
24' - 0"
EX. JOIST
EX. DOUBLE JOIST
4"
EX. JOIST
EX. JOIST
19' - 4 3/4"
24' - 9 3/4"
27' - 1 3/4"
38' - 0 3/4"

SYSTEM 4



SYSTEM 5 — BEAMS



SYSTEM 5 — PANELS

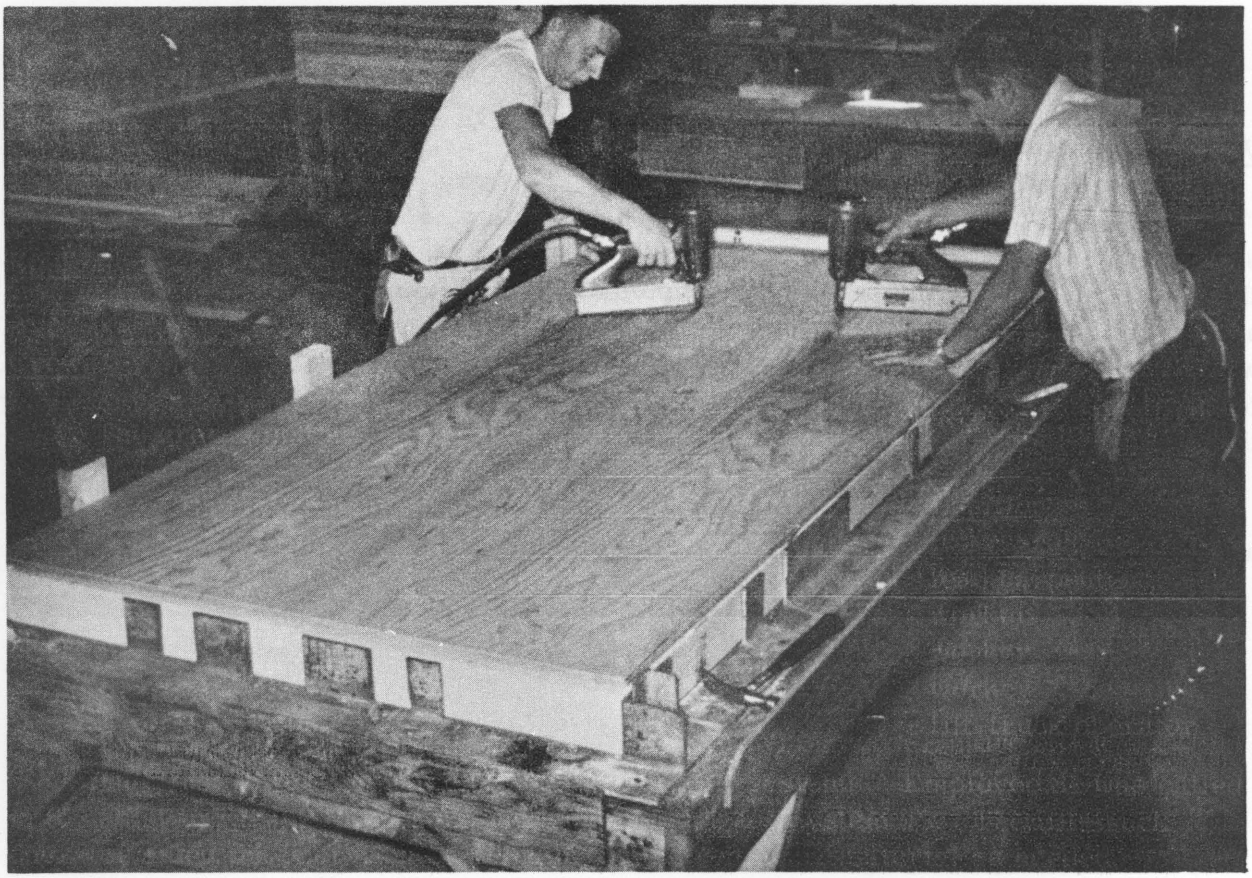
III. SHOP OPERATIONS

Work

System #5, the beam and panel component system, obviously required extensive shop work. In view of this fact, and in view of the fact that the shop ordinarily precut the cross bridging for the standard or customarily used joists system, it was decided at the preliminary conference, that, insofar as possible, materials for all systems would be precut, packaged, and then delivered to the site. The S4S board subflooring for System #1 and the matched subflooring for System #3 were exceptions to this rule--they were not precut.

The following list enumerates the operations carried out in the shop. The accompanying table number refers to the table that gives the labor times recorded.

System		Table
#1 -	Cutting joists to length	1A
	Cutting bridging	C
	Stacking and bundling for truck	
#2 -	Cutting joists to length	2A
	Cutting bridging	C
	Cutting plywood subfloor	2B
	Stacking and bundling for truck	
#3 -	Cutting joists to length	3A
	Cutting bridging	C
	Stacking and bundling for truck	
#4 -	Cutting joists to length	4A
	Cutting bridging	C
	Cutting plywood subfloor	4B
	Stacking and bundling for truck	
#5 -	Cutting and nailing beams	5A
	Cutting and nailing ledger strips to beam	5A
	Cutting panel ribs	5B
	Preparing panel jig and fabricating panels	
	Stacking and bundling for truck	



Shop fabrication of panels for System #5

Crew

The crew employed in the shop precutting fabricating work was as follows:

Employee number	Position
S1	lead carpenter
S2	worker
S3	worker
S4	worker
S5	lift-truck operator

The first three crew members worked on all systems. Employee S4 was called in to assist in nailing the beams and ledger strips for System #5. The lift-truck operator aided the operation by bringing in and removing material as needed.

Equipment

A radial saw was used to cut the joists, ledger strips, and bridging.

A vertical table plywood saw was used for cutting plywood sheets to specified sizes.

An air-operated power nailing machine was used in nailing the beams and ledger strips involved in System #5. Nails were started by hand, and the operation was completed with the power machine.

An air-operated, magazine-fed stapling machine was used in manufacturing the panels of System #5. Plywood was fastened to the ribs of the panels with $1\frac{1}{2}$" staples.

Materials were packaged by hand using a plastic strapping material.

A fork-lift truck was used for handling unprocessed materials as well as processed and packaged parts and pieces.

A standard jig for the wall panel framing system* was modified to serve as a jig for the floor panels.

Procedures

The lead carpenter set up the machines for the cutting operations. Jigs were set to cut the material to the dimensions shown on the layouts prepared by SHC-BRC, or as given to the shop foreman by the SHC-BRC representative. The workmen then handled, processed, and packaged the various pieces and parts. Packages were loaded on the delivery truck by fork-lift.

Box nails, rather than common, were used in fabricating the beams.

Time Records

Time records for shop operations are shown in the A, B, and C series tables. The times reported are fabrication times, along with discussion, measuring, and other nonproductive times related to the work. If nonproductive times were directly related to the system under fabrication, they were charged to that system. Such times included idle times resulting from the production process, tool care, jig preparation, and the like.

Certain times were prorated to the various systems. These times include "preliminary," the period devoted to assignment of work at the beginning of the day; "close shop"; and "coffee". These times were totalled by worker, and prorated by system in accordance with the amount of time otherwise recorded.

Lift-truck operator times was also prorated. It was difficult to record and assign this operation. The recorder was stationed in the shop and could not observe the operations of the lift-truck when out of the shop; hence, the records may not be complete. On the other hand, a substantial proportion of the recorded time occurred at the beginning of the work when the lift-truck operator was instructed to assemble the

*This system was developed by the SHC-BRC through a cooperative investigation with the Lumber Dealers Research Council. The system is designated "LU-RE-CO" by the LDRC.

material for the five systems, and was in and out of the shop for a period of 37 minutes. Some of the fabricated parts remained in the shop after the completion of the time recording; thus, a few minutes of lift-truck time were not recorded. This time was probably compensated for in that two full coffee breaks were charged to this project--an amount substantially greater than justifiable on a prorated basis.

In the final analysis, all recorded lift-truck operation time (including coffee times) was prorated to the systems on the basis of the number of trips which might be logically required by the system. The lift-truck time was prorated as follows:

System		Number of Trips	Time (in minutes)
#1 -	Truck lumber in	1	6
	Truck packages out	1	6
			12
#2 -	Truck lumber in	1	6
	Truck plywood in	1/3	2
	Truck packages out	1	6
			14
#3 -	Truck lumber	1	6
	Truck packages out	1	6
			12
#4 -	Truck lumber	1	6
	Truck plywood in	1/3	2
	Truck packages out	1	6
			14
#5 -	Truck lumber (2 x 10) in	1	6
	Truck lumber (2 x 4) in	1	6
	Truck beams out	2	12
	Truck lumber (2 x 4) in	1	6
	Truck plywood in	1/3	2
	Truck panels out	3	18
			50

Comments

The time required for modification of the wall-panel jig so that it could be used for the floor panels was nearly two hours. If the system were to be used frequently, one jig might be left set up for this work. For single jobs, a plywood and 2 x 4 jig might be constructed more simply. In the summary of costs, an adjustment has been made in System #5A (the adjusted system) for this factor.

There were some lost motions in the shop operations which would be eliminated with continued operation. The SHC-BRC prepared drawings and order schedules for the systems, but did not prepare a cutting schedule. This work was done by the

TABLE 1A

SYSTEM # 1 - SHOP LABOR - FRAMING
(2 x 8 Joists 16" o.c.)

Employee number	S1	S2	S3	S5	Total Time
	Time (in minutes)				
Prelim, job assignment#	10*	16*	16*		42*
Jigging, set	6				6
Carry joists		20			20
Sawing joists to length	20				20
Stacking joists			20		20
Strapping, packaging joists	9	15	15		39
Trucking joists				35*	35*
Trucking packages				2*	2*
Chargeable to system	35	35	35		105
General	10*	16*	16*	37*	79*
Total	45	51	51	37	184
23 July 1963 Start	1:00	1:00	1:00	1:00	
Stop	1:45	1:51	1:51	1:35	
Start				1:55	
Stop				1:57	
Total	45	51	51	37	184
Chargeable to system	35	35	35		105
Prorated	5	6	6	12	29
Total	40	41	41	12	134

*General time to be prorated

#Time from beginning of work day until start of production

TABLE 2A

SYSTEM # 2 - SHOP LABOR - FRAMING

(2 x 8 Joists 16" o.c.)

	S1	S2	S3	S5	
	Time (in minutes)				Total Time
Truck joists				6*	6*
Jigging, set up	5				5
Carry joists		25			25
Saw joists	25				25
Stack joists			25		25
Strap, package joists	6	7	7		20
Truck packages				2*	2*
Chargeable to system	36	32	32		100
General				8*	8*
Total	36	32	32	8	108
23 July 1963 Start	1:45	1:51	1:51	1:49	
Stop	2:21	2:23	2:23	1:55	
Start				2:27	
Stop				2:29	
Total	36	32	32	8	108
Chargeable to system	36	32	32		100
Prorated	5	5	5	12	27
Total	41	37	37	12	127

*General time to be prorated

TABLE 2B

SYSTEM # 2 - SHOP LABOR - SUBFLOOR
($\frac{1}{2}$" C-D Plywood)

Employee number	S1	S2	S3	S5	
	Time (in minutes)				Total Time
Truck plywood				1*	1*
Carry plywood		4			4
Cut plywood	19				19
Chargeable to system	19	4			23
General				1*	1*
Total	19	4		1	24
23 July 1963 Start				3:19	
Stop				3:20	
24 July 1963 Start	9:42	10:35			
Stop	10:01	10:39			
Total	19	4		1	24
Chargeable to system	19	4			23
Prorated	3	1		2	6
Total	22	5		2	29

*General time to be prorated

TABLE 3A

SYSTEM #3 - SHOP LABOR - FRAMING
(2 x 10 Joists 24" o.c.)

Employee number	S1	S2	S3	S5	
	Time (in minutes)				Total Time
Read plans, discuss		5	5		10
Jigging, set up	7				7
Carry joists		13			13
Saw joists	13				13
Stack joists			13		13
Strap, package joists	4	8	8		20
Truck packages				2*	2*
Chargeable to system	24	26	26		76
General				2*	2*
Total	24	26	26	2	78
23 July 1963 Start	2:21	2:23	2:23	3:12	
Stop	2:45	2:49	2:49	3:14	
Total	24	26	26	2	78
Chargeable to system	24	26	26		76
Prorated	4	4	4	12	24
Total	28	30	30	12	100

*General time to be prorated

TABLE 4A

SYSTEM # 4 - SHOP LABOR - FRAMING

(2 x 10 Joists 24" o.c.)

Employee number	S1	S2	S3	S5	Total Time
	Time (in minutes)				
Read plans, discuss	4				4
Carry joists		20			20
Saw joists	21				21
Stack joists			20		20
Strap, package joists		9	9		18
Truck packages				9*#	9*
Coffee	20*	20*	20*	20*	80*
Idle	4	4	4		12
Chargeable to system	29	33	33		95
General	20*	20*	20*	29*	89*
Total		53	53	29	184
23 July 1963 Start	2:45	2:49	2:49	2:49	
Stop	3:34	3:42	3:42	3:09	
Start				3:43#	
Stop				3:52	
Total	49	53	53	29	184
Chargeable to system	29	33	33		95
Prorated	5	6	6	12	29
Total	34	39	39	12	124

*General time to be prorated

#Labor actually performed by workman S2 who drove lift-truck to clear working area

TABLE 4B

SYSTEM # 4 - SHOP LABOR - SUBFLOOR
($\frac{1}{2}$" C-D Plywood)

Employee number	S1	S2	S3	S5	Total Time
		Time (in minutes)			
Truck plywood				1*	1*
Carry plywood		4			4
Cut plywood	19				19
Chargeable to system	19	4			23
General				1*	1*
Total	19	4		1	24
23 July 1963 Start				3:20	
Stop				3:21	
24 July 1963 Start	10:01	10:39			
Stop	10:20	10:43			
Total	19	4		1	24
Chargeable to system	19	4			23
Prorated	3	1		2	6
Total	22	5		2	29

*General time to be prorated

TABLE 5A

SYSTEM # 5 - SHOP LABOR - BEAMS

Employee number	S1	S2	S3	S4	S5	Total Time
	Time (in minutes)					
Prelim, job assignment#	10*	10*	10*			30*
Discuss, read plans	13	4	3			20
Saw beams	19					19
Carry ledgers		13	13			26
Saw ledgers	13					13
Carry 2 x 10		13	16			29
Nail beams & ledgers		101	104	74		279
Power nail	105					105
Close shop	5*	5*	5*	5*		20*
Tool care	6	11	6			23
Idle	3		9			12
Chargeable to system	159	142	151	74		526
General	15*	15*	15*	5*		50*
Total	174	157	166	79		576
23 July 1963 Start	3:34	3:42	3:42	4:46		
Stop	4:19	3:43	4:19	5:30		
Start	4:36	3:52	4:36			
Stop	5:30	4:19	5:30			
Start		4:36				
Stop		5:30				
24 July 1963 Start	7:00	7:00	7:00	7:40		
Stop	8:15	8:15	8:15	8:15		
Total	174	157	166	79		576
Chargeable to system	159	142	151	74		526
Prorated	24	24	25	5	24	102
Total	183	166	176	79	24	628

*General time to be prorated

#Time from beginning of work day until start of production

TABLE 5B

SYSTEM # 5 - SHOP LABOR - PANELS

Employee number	S1	S2	S3	S5	Total Time
	Time (in minutes)				
Discuss, read plans	5	5	5		15
Truck rib material				2*	2*
Truck plywood				1*	1*
Handle ribs		17	17		34
Saw ribs	17				17
Correct ribs		17	17		34
Jig for panels	57	28	28		113
Staple panels		53	53		106
Saw plywood		2	2		4
Carry plywood			8		8
Clean work area	3				3
Tool care	5				5
Coffee	17*	17*	17*	17*	68*
Idle				4*	4*
Chargeable to system	87	122	130		339
General	17*	17*	17*	24*	75*
Total	104	139	147	24	414
23 July 1963 Start	4:19	4:19	4:19	3:21	
Stop	4:36	4:36	4:36	3:28	
24 July 1963 Start	8:15	8:15	8:15		
Stop	9:42	8:36	8:36		
Start		8:54	8:54	9:25	
Stop		10:35	10:43	9:42	
Total	104	139	147	24	414
Chargeable to system	87	122	130		339
Prorated	13	21	22	26	82
	100	143	152	26	421

*General time to be prorated

TABLE C

SYSTEMS # 1, # 2, # 3, # 4, - SHOP LABOR - BRIDGING
(Total labor for all systems)

Employee number	S1	S2	S3	S5	
	Time (in minutes)				Total Time
Preliminary	5				5
Discuss	7	7	7		21
Jig for bridging	17				17
Saw bridging	23				23
Carry bridging		18	18		36
Idle		4	4		8
Total	52	29	29		110
23 July 1963 Start	10:20	10:43	10:43		
Stop	11:12	11:12	11:12		
Total	52	29	29		110

lead carpenter with assistance from the SHC-BRC representative. If the cutting schedules are prepared before hand, the shop times will obviously be reduced somewhat; however, office or drafting time would then be required to accomplish this work.

There was also some confusion in the matter of the plywood subfloor. Twenty-nine plywood panels were required per house, some of these cut to size. In at least one instance 29 full panels were loaded on the trucks in addition to the cut panels.

Some difficulties were encountered in fabricating the doubled 2 x 10 beams of System #5 due to the difference in crown, which occurred in some of the 2 x 10 material. This fabrication difficulty, as well as the labor cost due to nailing, would be eliminated by the purchase of 4 x 10 material.

IV. FIELD OPERATIONS

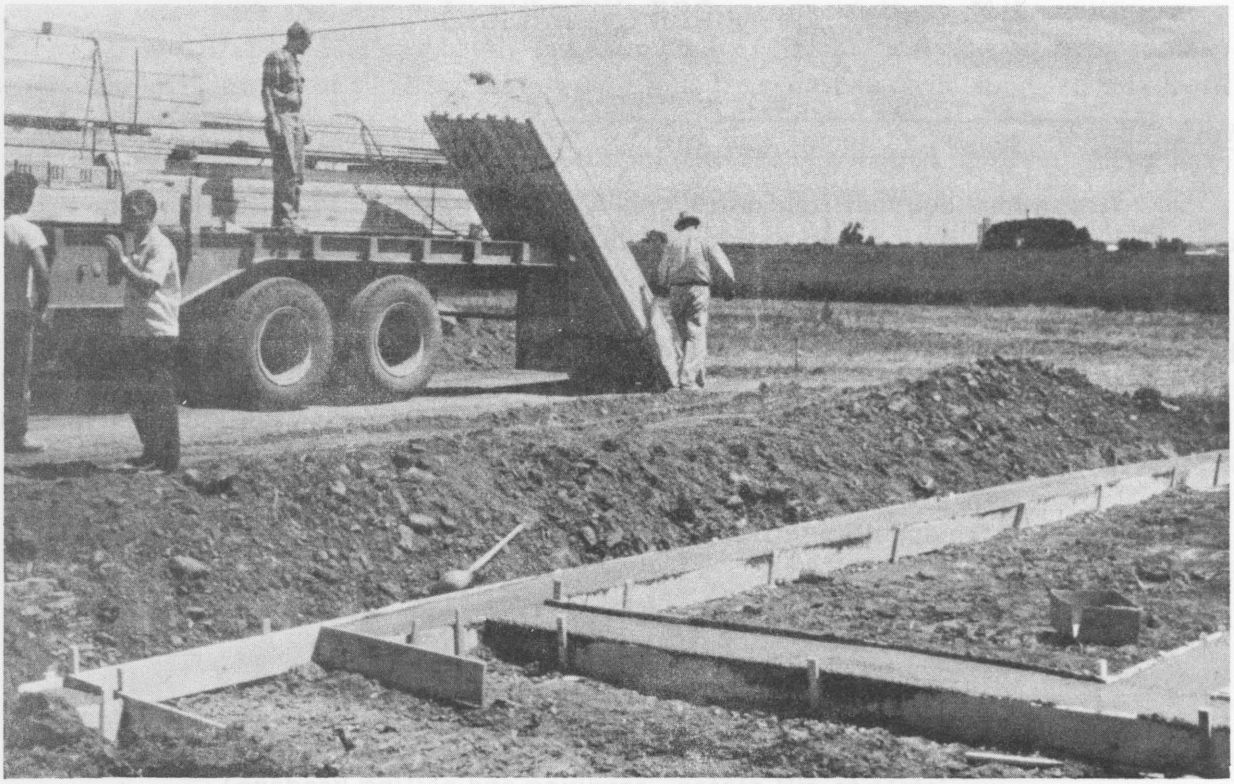
Work

It was intended that field work would be limited to the installation of floor joists, headers (rim or band joists), bridging and subflooring with the field cutting operation limited to non-standard bridging and board and matched subflooring. Some other cutting actually occurred in the field due to irregular foundations and the fact that carpenters did not start at the indicated position.

According to the design of the study, no records were kept of the construction and placement of the center girder or the sills.

A list of the specific activities involved in the field construction phase and recorded in the data is as follows:

System		Table
#1	Installation of framing (including measuring for joists placement, carrying joists, toe-nailing joists to sill plates, carrying and nailing headers)	1D
	Installation of bridging (including carrying scaffold boards and bridging, prenailing bridging, and nailing bridging to top of joists)	1E
	Installation of board subfloor (including cutting and nailing boards)	1F
#2	Installation of joists	2D
	Installation of bridging	2E
	Installation of plywood subfloor (including carrying, placing, and nailing plywood)	2F
#3	Installation of joists	3D
	Installation of bridging	3E
	Installation of matched subfloor	3F
#4	Installation of joists	4D
	Installation of bridging	4E
	Installation of plywood subfloor	4F
#5	Installation of beams (including installation of extra joists at end), headers, and blocking	5D
	Installation of floor panels (including installation of plywood filler panels at end of building)	5F



Unloading packaged materials at site

Installation of 2 x 8 joists (System #2)

Crew

The crew employed in the field work was as follows:

Employee number	Position
#1	subcontractor
#2	laborer
#3	carpenter
#4	lead carpenter

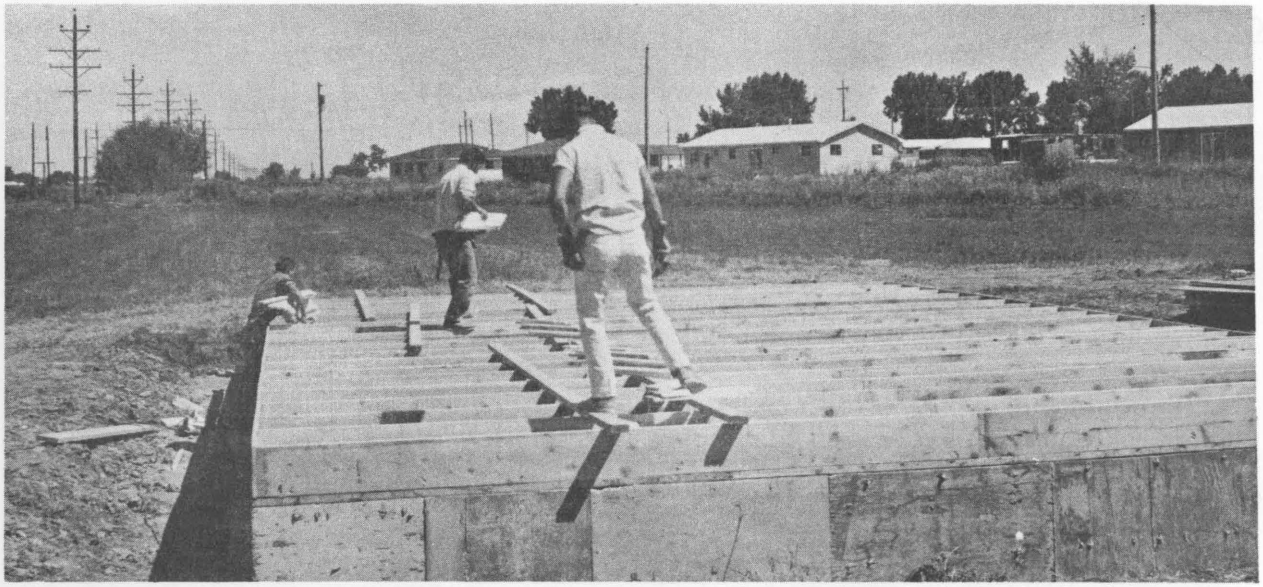
The last three crew members participated in the construction of all systems, while the subcontractor aided the operation from time to time.

Procedures

Material was dumped from the truck at the site and was not placed advantageously for the operation. Material was dumped at the corner diagonally opposite the starting point. Some 1 x 8 header material was broken in the dumping process.

Joist layout was clearly indicated on the plan prepared by SHC-BRC for each house. The plans specified the starting point for the layout and all extra joists or doubled joists were located with reference to the starting point. The SHC-BRC observer pointed out the starting point arrangement to the subcontractor. Nevertheless, layout difficulties occurred, due to the fact that the workmen were not normally required to provide doubled or extra joists, and that the instructions as to starting point were not received or were ignored. This error was repeated and reoccurred as late as System #4.

Application of 1 x 8 header (System #4)



Installation of bridging (System #4)

Other difficulties occurred because the foundations were not properly sized. House #1 had dimensions of 24'-2 1/8" x 38'-0 1/2"; house #2, 24'-1" x 38'-1 3/4"; house #3, 24'-0 1/8" x 38'-1 1/4"; house #4 and #5 were properly built with dimensions of 24'-0" x 38'-0 3/4".

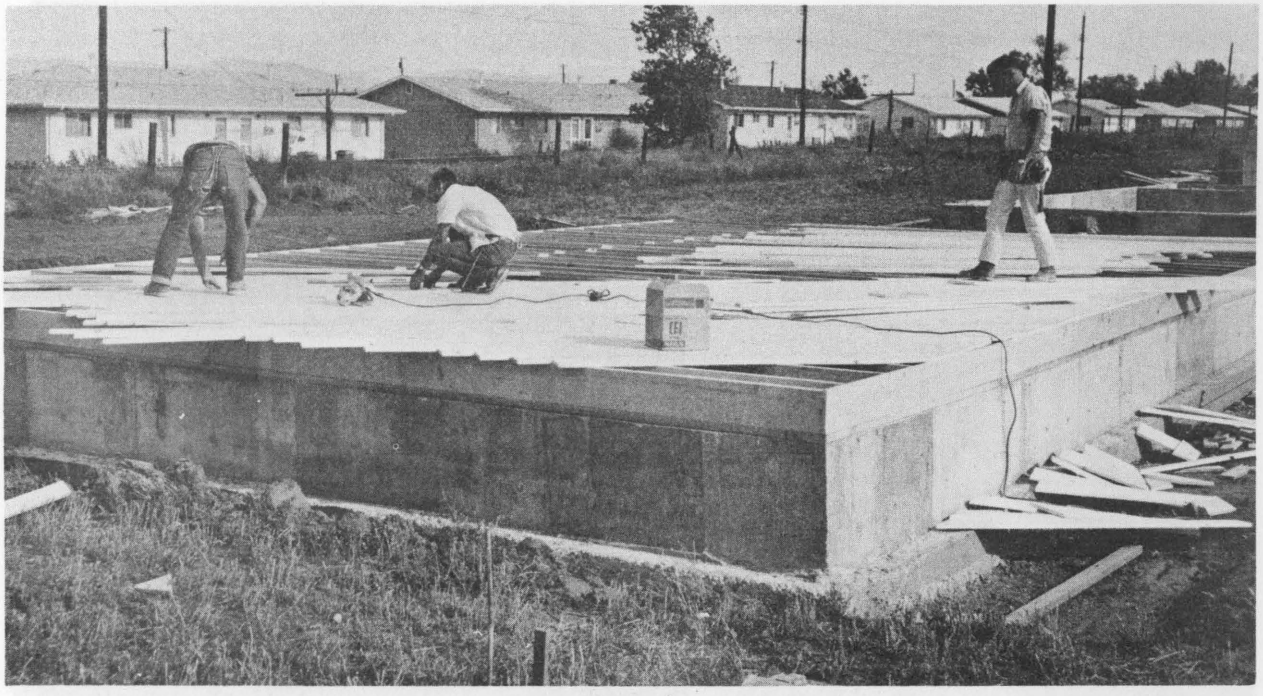
The subcontractor commonly used one-inch material for header (band) joists. Accordingly, this procedure was used on Systems #1 through #4. The wide spacing (4' o.c.) of the beams of System #5 required the use of 2 x 10 header joists.

The one-inch material had apparently been sized after drying while the joists were sized before drying. Thus, the header (band joists) were wider than the joists. This resulted in a height difference between the joists and the header where they joined.

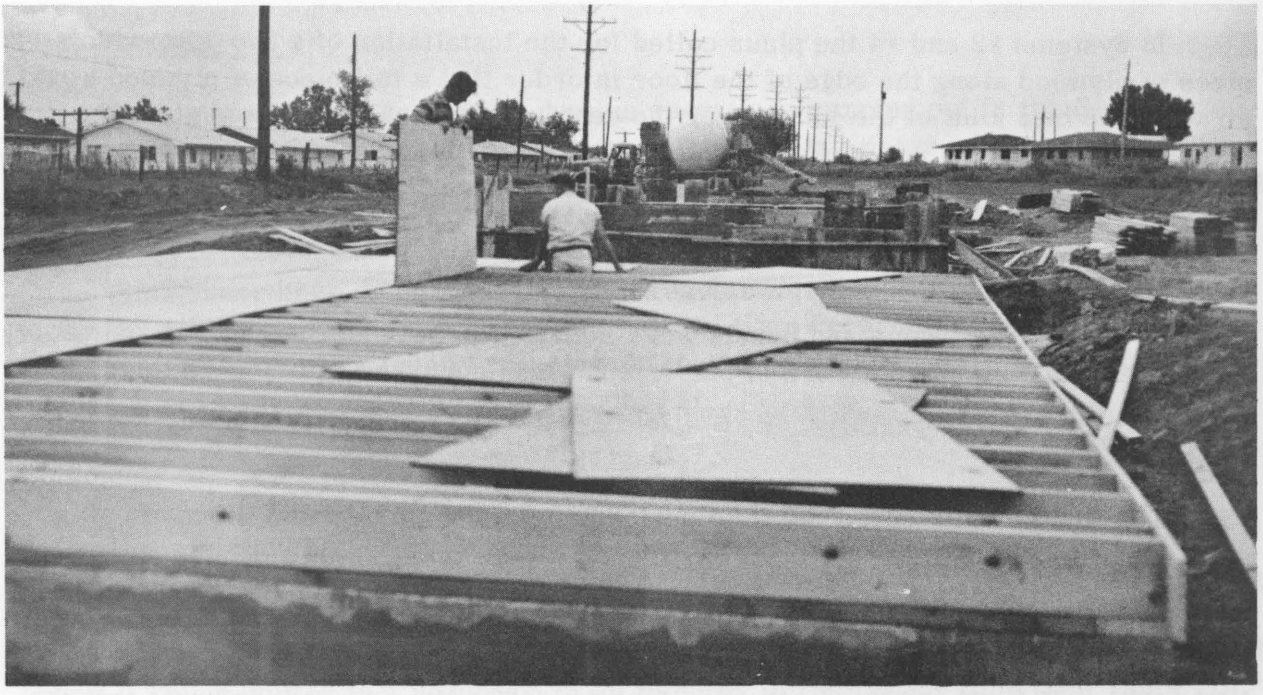
Bridging was installed in the standard manner. Nails were started in the bridging, and the bridging was nailed to the top of each joist. This operation was carried out from a few planks which had been placed on top of the joists.

In Systems #3 and #4, in which 2 x 10 joists spaced 24 inches on center were used, 2 x 10 blocking was used for bridging between closely spaced joists. This was done at the direction of the subcontractor. Material was obtained from scrap on the site. This work resulted in higher labor times for installing bridging in Systems #3 and #4. The normal process used in installing the diagonal S4S boards was to cut one end of the board, tack the board in place and saw the other end in place. The next board was then fitted. Subsequently, the nailing was completed. All nailing was done by hand; box nails were used. Cutting was done with an 8" power saw.

The lumber dealer was unable to supply end-matched subflooring material for System #3. It was decided that 1 x 6 tongue and groove material should be used, and



Installation of 1 x 6 S4S diagonal subfloor (System #1)



Installation of 1/2" plywood subfloor (System #2)

Installing floor panels (System #5)

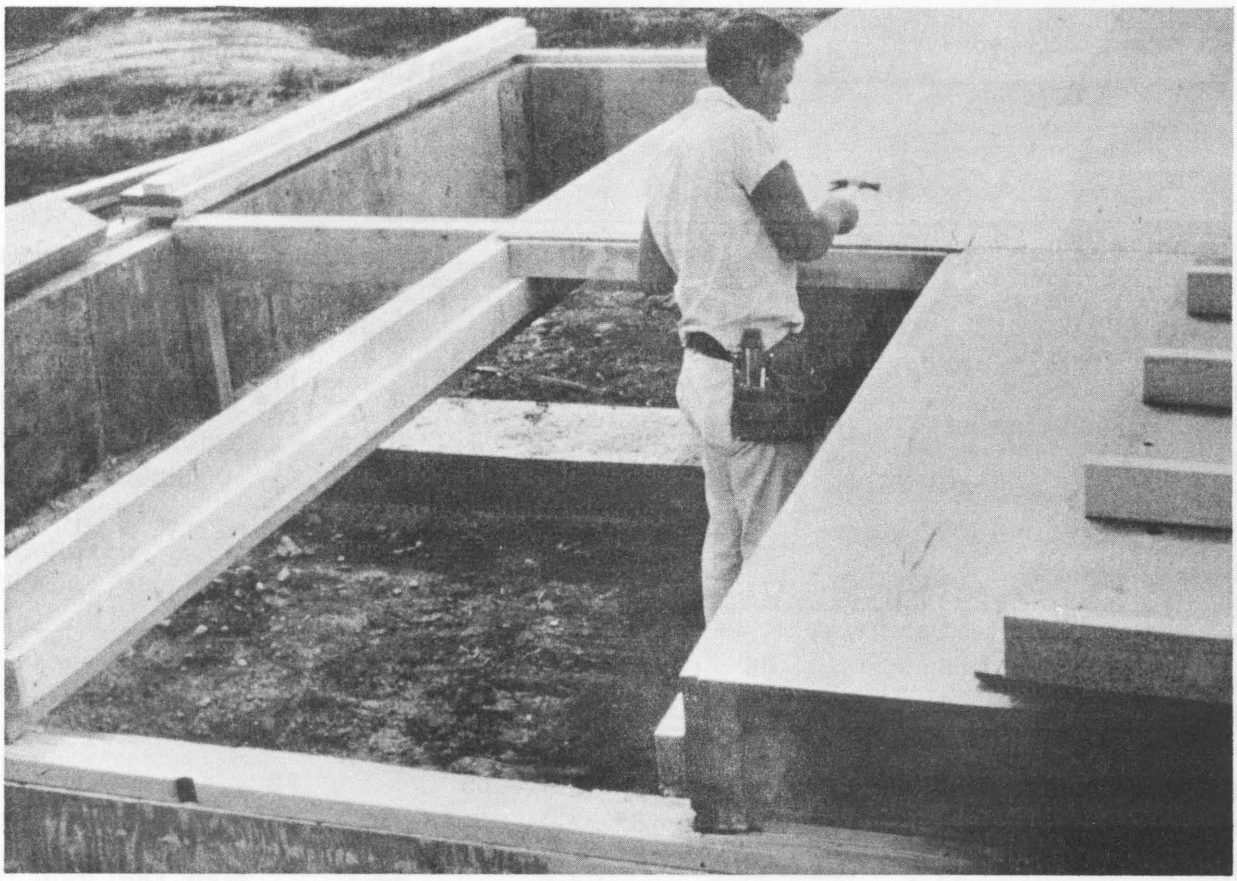
that the butt ends of this material would be installed as though it were end-matched. This procedure was used in order to gain the savings normally attributable to end-matched material, that is, the savings due to less sawing and less waste.

In Systems #2 and #4 the plans called for the installation of a two-foot-wide piece of plywood along the edge of the floor in order that a full piece of plywood would straddle the butt joint of the joists over the center girder. Plywood was placed according to the plan, and tacked in place. Following this operation, the nailing was completed. Box nails were used. Nailing was spaced approximately 8 inches on center. Unsupported edges of the plywood were not blocked since 25/32" finish flooring was to be used.

In System #5, beams and panels were installed in sequence a space at a time, thereby eliminating some errors of placement which occurred on other systems.

Weather

The weather influenced the field performance to some degree. House #1 was started on the 25th of July, an ideal day (recorded as "unbelievable" by the observer). It rained the night of the 25th and the area under the floor was muddy, but the day of the 26th was again "perfect". House #1 and #2 were completed this day. House #3 was completed on July 27, 1963, a cold and overcast day. Houses #4 and #5 were completed on July 29, 1963, another perfect day. The time records indicate that the cold day resulted in less time being spent drinking water.



Installing floor panels (System #5)

Time Records

Time was recorded for all productive operations carried out in the field as well as idle time related to the procedure, pauses for drinking water, discussion, etc. No time was recorded for the subcontractor when he was on the job but not contributing to the progress of the work.

Time recordings do not coincide with regular working hours since occasionally the crew started or stopped early or late. Also, time recordings are not continuous since the crew was occasionally transferred to work outside of the study, such as installing sills and girders, or to other jobs.

Comments

Measurement and layout time seems excessive on System #1. This is probably due to the newness of the idea of using precut material and to the problem of installing extra and doubled joists. Some adjustment was made for this extra time by eliminating one layout operation which was repeated due to an error committed during the initial layout. This resulted in a reduction of 39 minutes in field labor time (see Table 1D).

TABLE 1D

SYSTEM # 1 - FIELD LABOR - FRAMING
(2 x 8 Joists 16" o.c.)

Employee number	#1	#2	#3	#4	
	Time (in minutes)				Total Time
Measure	7		10	11	28
Measure and correct	9#	10#	10#	10#	39#
Discussion	18			2	20
Carry joists	18	31	7	7	63
Nail joists		11	33	40	84
Carry headers		1			1
Nail headers		12	13	11	36
Tool care					
Water	2*	6*	14*	7*	29*
Idle		6	2	1	9
Chargeable to system	43	61	65	72	241
General	2*	6*	14*	7*	29*
Repetition	9#	10#	10#	10#	39#
Total	54	77	89	89	309
27 July 1963 Start	2:33	2:33	2:33	2:33	
Stop	3:17	3:50	4:02	4:02	
Start	3:45				
Stop	3:55				
Total	54	77	89	89	309
Chargeable to system	43	61	65	72	241
Prorated	3	4	5	5	17
Total	46	65	70	77	258

*General time to be prorated

#Correction time not included in final summation due to the fact that these times were repetitious

TABLE 1E

SYSTEM # 1 - FIELD LABOR - BRIDGING
(1 x 4 Cross Bridging)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure			2	2	4
Discussion					
Place scaffolding	1				1
Carry bridging			6	8	14
Nail bridging		49	17	17	83
Tool care		10	11	9	30
Water			11*	11*	22*
Chargeable to system	1	59	36	36	132
General			11*	11*	22*
Total	1	59	47	47	154
25 July 1963 Start	3:55	3:50	4:02	4:02	
Stop	3:56	4:35	4:35	4:35	
26 July 1963 Start		7:00	7:00	7:00	
Stop		7:14	7:14	7:14	
Total	1	59	47	47	154
Chargeable to system	1	59	36	36	132
Prorated		4	3	3	10
Total	1	63	39	39	142

*General time to be prorated

TABLE 1F

HOUSE # 1 - FIELD LABOR - SUBFLOOR
(1 x 6 S4S Diagonal)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure		2	4	7	13
Discussion		5	5		10
Carry and handle boards		21	23	6	50
Saw and nail boards				86	86
Nail boards		116	128	74	318
Tool care		3	4	4	11
Water			7*	6*	13*
Idle		3	12		15
Chargeable to system		150	176	177	503
General			7*	6*	13*
Total		150	183	183	516
26 July 1963 Start		7:14	7:14	7:14	
Stop		8:32	10:17	10:17	
Start		9:05			
Stop		10:17			
Total		150	183	183	516
Chargeable to system		150	176	177	503
Prorated		11	13	13	37
Total		161	189	190	540

*General time to be prorated

TABLE 2D

SYSTEM # 2 - FIELD LABOR - FRAMING
(2 x 8 Joists 16" o.c.)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure			2	7	9
Discussion & reading plans			7	2	9
Carry joists		35	11	11	57
Nail and handle joists			28	28	56
Carry headers		2			2
Nail headers		14	8	12	34
Tool care			2		2
Water		7*	3*	3*	13*
Idle		6	4	2	12
Chargeable to system		57	62	62	181
General		7*	3*	3*	13*
Total		64	65	65	194
26 July 1963 Start			12:51	12:51	
Stop			12:53	12:53	
Start		1:19	1:20	1:20	
Stop		2:23	2:23	2:23	
Total		64	65	65	194
Chargeable to system		57	62	62	181
Prorated		4	5	4	13
Total		61	67	66	194

*General time to be prorated

TABLE 2E

SYSTEM # 2 - FIELD LABOR - BRIDGING
(1 x 4 Cross Bridging)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure		2	2	2	6
Discussion					
Place scaffolding			6		6
Carry bridging		11		6	17
Nail bridging		15	16	16	47
Tool care					
Water			2*	2*	4*
Idle		4			4
Chargeable to system		32	24	24	80
General			2*	2*	4*
Total		32	26	26	84
26 July 1963 Start		2:23	2:23	2:23	
Stop		2:55	2:46	2:46	
Start			2:53	2:53	
Stop			2:56	2:56	
Total		32	26	26	84
Chargeable to system		32	24	24	80
Prorated		2	2	2	6
Total		34	26	26	86

*General time to be prorated

TABLE 2F

SYSTEM # 2 - FIELD LABOR - SUBFLOOR
($\frac{1}{2}$" C-D Plywood)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure, layout			2	2	4
Discussion					
Carry plywood		13	5	5	23
Nail plywood		38	54	55	147
Tool care					
Water		3*	3*	2*	8*
Idle		4			4
Chargeable to system		55	61	62	178
General		3*	3*	2*	8*
Total		58	64	64	186
26 July 1963 Start		2:55	2:46	2:46	
Stop		3:53	2:53	2:53	
Start			2:56	2:56	
Stop			3:53	3:53	
Total		58	64	64	186
Chargeable to system		55	61	62	178
Prorated		4	4	5	13
Total		59	65	67	191

*General time to be prorated

TABLE 3D

SYSTEM # 3 - FIELD LABOR - FRAMING
(2 x 10 Joists 24" o. c.)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure, layout	9			1	10
Carry joists		34	3	1	38
Nail and handle joists			32	33	65
Carry headers		4			4
Nail headers			9	9	18
Tool care	1		3		4
Idle		2	2		4
Chargeable to system	10	40	49	44	143
General					
Total	10	40	49	44	143
27 July 1963 Start	7:47	7:53	7:54	7:55	
Stop	7:57	8:32	8:43	8:39	
Start		8:39			
Stop		8:40			
Total	10	40	49	44	143
Chargeable to system	10	40	49	44	143
Prorated	1	3	4	3	11
Total	11	43	53	47	154

TABLE 3E

SYSTEM # 3 - FIELD LABOR - BRIDGING
(1 x 4 Cross Bridging)

Employee number	#1	#2	#3	#4	Total Time
	Time (in minutes)				
Measure, layout	2		4		6
Discussion	1	1			2
Place scaffolding		6	5	10	21
Carry bridging		13			13
Nail bridging	29		14	13	56
Measure and saw solid bridging	9				9
Nail solid bridging		1	2	5	8
Tool care	2		2		4
Water					
Idle	13	6			19
Chargeable to system	56	27	27	28	138
General					
Total	56	27	27	28	138
27 July 1963 Start	8:06	8:32	8:43	8:39	
Stop	9:01	8:39	9:10	9:07	
Start	9:04	8:40			
Stop	9:05	9:00			
Total	56	27	27	28	138
Chargeable to system	56	27	27	28	138
Prorated	4	2	2	2	10
Total	60	29	29	30	148

TABLE 3F
SYSTEM # 3 - FIELD LABOR - SUBFLOOR
(1 x 6 T & G end-matched diagonal)#

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure	1				1
Discussion	2		3	3	8
Carry and handle boards		67			67
Saw and nail boards	8			17	25
Nail boards	67	46	102	99	314
Tool care	1				1
Water		8*	8*		16*
Idle		23	21	18	62
Chargeable to system	79	136	126	137	478
General		8*	8*		16*
Total	79	144	134	137	494
27 July 1963 Start	9:01	9:00	9:10	9:07	
Stop	9:04	11:24	11:24	11:24	
Start	9:05				
Stop	10:17				
Start	10:22				
Stop	10:26				
Total	79	144	134	137	494
Chargeable to system	79	136	126	137	478
Prorated	6	10	9	10	35
Total	85	146	135	147	513

*General time to be prorated
#Square end material used, but laid to simulate end-matched material

TABLE 4D
SYSTEM # 4 - FIELD LABOR - FRAMING
(2 x 10 Joists 24" o.c.)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure and layout			8	8	16
Discussion					
Carry joists		22			22
Nail joists			28	30	58
Correcting headers			2	2	4
Correct joists			9	9	18
Carry headers					
Nail headers			6	6	12
Sawing headers			5	9	14
Tool care					
Idle		4	16	10	30
Water					
Chargeable to system		26	74	74	174
General					
Total		26	74	74	174
29 July 1963 Start		8:37	8:26	8:26	
Stop		9:03	8:34	8:34	
Start			8:38	8:38	
Stop			8:52	8:52	
Start			9:16	9:16	
Stop			9:57	9:57	
Start			10:01	10:01	
Stop			10:03	10:03	
Start			10:22	10:22	
Stop			10:31	10:31	
Total		26	74	74	174
Chargeable to system		26	74	74	174
Prorated		2	5	6	13
Total		28	79	80	187

TABLE 4E

SYSTEM # 4 - FIELD LABOR - BRIDGING

(1 x 4 Cross Bridging)#

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure layout				3	3
Discussion					
Place scaffolding			4	2	6
Carry bridging		10		7	17
Nail bridging		54	8	8	70
Measure & saw solid bridging		3		9	12
Nail solid bridging		9	10		19
Carry solid bridging		1			1
Tool care					
Water		19*	12*		31*
Idle		9	9		18
Chargeable to system		86	30	29	145
General		19*	12*		31*
Total		105	42	29	176
29 July 1963 Start		9:03	9:57	9:57	
Stop		10:14	10:01	10:01	
Start		10:16	10:03	10:03	
Stop		10:50	10:22	10:22	
Start			10:31	10:31	
Stop			10:50	10:37	
Total		105	42	29	176
Chargeable to system		86	30	29	145
Prorated		7	2	2	11
Total		93	32	31	156

*General time to be prorated

#Some solid bridging added in field

TABLE 4F

SYSTEM # 4 - FIELD LABOR - SUBFLOOR
($\frac{1}{2}$" C-D Plywood)

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Measure layout					
Discussion					
Carry plywood		18	6	2	26
Nail plywood		25	37	42	104
Tool care		4	4	4	12
Water		7*	10*	22*	39*
Idle		5			5
Chargeable to system		52	47	48	147
General		7*	10*	22*	39*
Total		59	57	70	186
29 July 1963 Start		10:14	10:50	10:37	
Stop		10:16	11:47	11:47	
Start		10:50			
Stop		11:47			
Total		59	57	70	
Chargeable to system		52	47	48	147
Prorated		4	3	4	11
Total		56	50	52	158

*General time to be prorated

TABLE 5D

SYSTEM # 5 - FIELD LABOR - BEAMS

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Carry beams		18	8	10	36
Nail beams			22	20	42
Correct beam spacing			3	4	7
Carry joists			2	2	4
Nail joists			2	2	4
Nail headers			10	10	20
Tool care					
Water		5*	6*	6*	17*
Idle#		12			12
Chargeable to system		30	47	48	125
General		5*	6*	6*	17*
Total		35	53	54	142
Chargeable to system		30	47	48	125
Prorated		2	3	4	9
Total		32	50	52	134

*General time to be prorated

#Idle time prorated between beams and panels

TABLE 5F

SYSTEM # 5 - FIELD LABOR - PANELS

Employee number	#1	#2	#3	#4	
		Time (in minutes)			Total Time
Carry panels		20	11	7	38
Nail panels and plywood edges		35	35	37	107
Carry plywood pieces			1	1	2
Nail plywood pieces			2	2	4
Tool care					
Water		5*	5*	6*	16*
Idle#		12			12
Chargeable to system		67	49	47	163
General		5*	5*	6*	16*
Total		72	54	53	179

(The following times include both beams and panels)

29 July 1963 Start		1:30	1:30	1:30	
Stop		3:17	3:17	3:17	
Total		107	107	107	321
Chargeable to system		67	49	47	163
Prorated		5	4	3	12
Total		72	53	50	175

*General times to be prorated

#Idle time prorated between beams and panels

More attention to plans and instructions would result in a reduction of errors and layout time.

The use of a machine nailer would reduce production time.

V. COSTS

Material Costs

The M series of tables list the materials used for each of the systems and their cost. Materials are priced at the retail price charged by the supplier to the contractor. Retail prices included the precutting of the bridging, but did not include precutting of any other material. Actual precutting times are shown in the A and B series of tables, and precutting costs, based on $3.00 per hour shop labor are shown in the LABOR COSTS table, page 55.

Precutting charges are very often based on the board feet and/or square feet of material processed. The actual precutting times of Systems #1 through #4 are tabulated below. These costs do not include any allowance for profit and overhead which would normally be charged by the retailer for the precutting operation.

PRECUTTING COSTS

System	Part	Quantity	Charge	Unit Charge
#1	Joists, etc.	1222 bm	$6.70	$.0055/bm
#2	Joists, etc.	1139 bm	6.35	.0056/bm
	Plywood	9 panels	1.45	.16/panel
#3	Joists, etc.	1070 bm	5.00	.0047/bm
#4	Joists, etc..	1003 bm	6.22	.0062/bm
	Plywood	9 panels	1.45	.16/panel

Labor Costs

Labor costs are based on an average rate of $3.00 per hour for shop work and $3.60 per hour for field operations. It is assumed that this rate does not include allowance for overhead and profit which would be charged by the shop operator or the field subcontractor. Each individual that evaluates this report will have to make adjustments for his own rates for labor, overhead, and profit.

Framing Costs

Framing costs in order of overall cost, lowest to highest, are given below:

TABLE 1M

SYSTEM # 1 - MATERIALS

FRAMING (2 x 8 joists 16" o.c.)

Joists	33 - 2 x 8 x 12'	528 bm		
	4 - 2 x 8 x 11' - 11 1/4"	64		
	31 - 2 x 8 x 12' - 10½"	578.66		
		1,170.66	@ .125	$146.33
Headers	4 - 1 x 8 - 12'	32		
	2 - 1 x 8 - 14'	18.66		
		50.66	@ .11	5.58

BRIDGING (1 x 4 cross bridging)

116 pieces	- 1 x 4 (for 16" spacing)		@ .045 ea.#	5.22

SUBFLOOR (1 x 6 S4S Diagonal)

	1 x 6 S4S	1,100 bm	@ .11	121.00
Total				$278.13

#This price for bridging includes allowance for shop labor employed in cutting bridging

TABLE 2M

SYSTEM # 2 - MATERIALS

FRAMING (2 x 8 joists 16" o.c.)

Joists	68 - 2 x 8 x 11'-11 1/4"	1,088 bm	@ .125	$136.00
Headers	4 - 1 x 8 x 12'	32		
	2 - 1 x 8 x 14'	18.66		
		50.66	@ .11	5.58

BRIDGING (1 x 4 cross bridging)

116 pieces	- 1 x 4 (for 16" spacing)	@ .045 ea.#	5.22

SUBFLOOR ($\frac{1}{2}$" C-D plywood)

29 panels	- 4' x 8' x $\frac{1}{2}$"	@4.00	116.00

Total $262.80

#This price for bridging includes an allowance for shop labor

TABLE 3M

SYSTEM # 3 - MATERIALS

FRAMING (2 x 10 joists 24" o.c.)

Joists	23 - 2 x 10 x 12'	460 bm		
	20 - 2 x 10 x 12'-10½"	466.66		
	4 - 2 x 10 x 11'-11 1/4"	80		
		1,006.66	@ .125	$125.83
Headers	4 - 1 x 10 x 12'	40		
	2 - 1 x 10 x 14'	23.33		
		63.33	@ .11	6.97

BRIDGING (1 x 4 cross bridging)#

76 pieces	- 1 x 4 (for 24" o.c.)	5.22

SUBFLOOR (1 x 6 T & G end-matched diagonal)*

1 x 6 T & G	1,100 bm	@ .135	148.50
Total			$286.52

#Some solid bridging added in field, using waste from girder construction

*Material was actually square-end, but it was laid to simulate end matched material

TABLE 4M

SYSTEM # 4 - MATERIALS

FRAMING (2 x 10 joists 24" o.c.)				
Joists	47 - 2 x 10 x 11'-11 1/4"	940 bm	@ .125	$117.50
Headers	4 - 1 x 10 x 12'	40		
	2 - 1 x 10 x 14'	23.33		
		63.33	@ .11	6.97
BRIDGING (1 x 4 cross bridging)#				
76 pieces	- 1 x 4 (for 24" o.c.)			5.22
SUBFLOOR ($\frac{1}{2}$" C-D plywood)				
29 panels	- 4' x 8' x $\frac{1}{2}$"		@4.00	116.00
Total				$245.69

#Some solid bridging added in field using wasted material from girder construction

TABLE 5M

SYSTEM # 5 - MATERIALS

FRAMING (double 2 x 10 beams 48" o.c.)

Beams	18 - 2 - 2 x 10 x 11'-10 3/8"	720 bm		
Joists	6 - 2 x 10 x 11'-10 3/8"	120		
		840	@ .125	$105.00
Headers	4 - 2 x 10 x 12'	80		
	2 - 2 x 10 x 14'	46.66		
		126.66	@ .125	15.83
Ledgers	36 - 2 x 4 x 11' -10 3/8"	288	@ .125	36.00

PANELS - TYPE A ($\frac{1}{2}$" C-D plywood with 4 - 2 x 4)

Plywood	18 - 4' x 8' x $\frac{1}{2}$" C-D		@4.00	72.00
Ribs	72 - 2 x 4 x 44 3/4"	192 bm	@ .125	24.00

PANELS - TYPE B ($\frac{1}{2}$" C-D plywood with 3 - 2 x 4)

Plywood	9 - 4' x 8' x $\frac{1}{2}$" C-D		@4.00	36.00
Ribs	27 - 2 x 4 x 44 3/4"	72 bm	@ .125	9.00

PANELS - FILLER

Plywood	3 - 2' x 8' x $\frac{1}{2}$" C-D plywood = 2 panels		@4.00	8.00
Blocking	4 - 2 x 4 x 1'	2.66 bm	@ .125	.33
Total				$306.16

LABOR COSTS

	Shop Labor		Field Labor		Total Labor	
	Time	Cost	Time	Cost	Time	Cost
System #1						
Framing	134	$ 6.70	258	$ 15.48	392	$ 22.18
Subfloor			540	32.40	540	32.40
Subtotal	134	6.70	798	47.88	932	54.48
Bridging			142	7.52	142	7.52
Total	134	$ 6.70	940	$ 55.40	1,074	$ 62.10
System #2						
Framing	127	6.35	194	11.64	321	17.99
Subfloor	29	1.45	191	11.46	220	12.91
Subtotal	156	7.80	385	23.10	541	30.90
Bridging			86	5.16	86	5.16
Total	156	$ 7.80	471	$ 28.26	627	$ 36.06
System #3						
Framing	100	5.00	154	9.24	254	14.24
Subfloor			513	30.78	513	30.78
Subtotal	100	5.00	667	40.02	767	45.02
Bridging			148	8.88	148	8.88
Total	100	$ 5.00	815	$ 48.90	915	$ 53.90
System #4						
Framing	124	6.20	187	11.22	311	17.42
Subfloor	29	1.45	158	9.48	187	10.93
Subtotal	153	7.65	345	20.70	498	28.35
Bridging			156	9.36	156	9.36
Total	153	$ 7.65	501	$ 30.06	654	$ 37.71
System #5						
Beams	628	31.40	134	8.04	762	39.44
Panels	421	21.05	175	10.50	596	31.55
Totals	1,049	$ 52.45	309	$ 18.54	1,358	$ 70.99

System	Description	Labor	Material	Total
#4	2 x 10 joists, 24" o.c. butted	$17.42	$124.47	$141.89
#3	2 x 10 joists, 24"o.c. lapped	14.24	132.80	147.04
#2	2 x 8 joists, 16" o.c. butted	17.99	141.58	159.57
#6	4 x 10 beams, 48" o.c. butted	29.84	129.83	159.67
#1	2 x 8 joists, 16" o.c. lapped	22.18	151.91	174.09
#5	2 - 2 x 10 beams, 48" o.c.butted	39.44	156.83	196.27

It is likely that labor cost of System #1 was unduly high because it was the system constructed first; however, a reduction in labor costs will not change its rank in the above listing.

It is interesting to note that the overall costs of each framing system other than System #6, the modified component system, is in direct relation to the material cost of the framing. It is also noteworthy that the most expensive conventional system is the one most commonly used.

From these cost figures, the following conclusions can be drawn:

2 x 10 joists spaced 24 inches on center were less costly than 2 x 8 joists spaced 16 inches on center.

Systems with joists butted over the center girder and tied together with the plywood subfloor were less costly than comparable systems with a lap joint at the center.

Subflooring Costs

Subflooring costs in order of overall costs, lowest to highest, are given below:

System	Description	Labor	Material	Total
#4	1/2" plywood	$10.93	$116.00	$126.93
#2	1/2" plywood	12.91	116.00	128.91
#1	1 x 6 S4S	32.40	121.00	153.40
#6	Panels (Modified)	27.05	149.33	176.38
#3	1 x 6 T & G	30.78	148.50	179.28
#5	Panels	31.55	149.33	180.88

From the above data the following conclusions can be drawn concerning the cost of subflooring under 25/32" strip finish flooring:

The 1/2" plywood subfloor resulted in both the lowest material and labor cost for subflooring. The combined material and labor cost was substantially lower than that of the other subflooring materials.

The savings (reduced labor and reduced waste) gained by installing 1 x 6 T & G end-matched subflooring did not offset the added cost of this material as compared to 1 x 6 S4S boards.

Bridging Costs

The cost of cutting bridging is included in the price of bridging to the builder. The overall costs may be summarized as follows:

COSTS OF BRIDGING

System	Field Labor	Material	Total
#1	$7.52	$5.22	$12.74
#2	5.16	5.22	10.38
#3	8.88	5.22	14.10
#4	9.36	5.22	14.58
Average cost	$7.73	$5.22	$12.95

These are not complete bridging costs as the bottom ends of the bridging remained to be nailed to the joists. Since this work would have to be done from the crawl space, it would be difficult to perform and would likely take twice as long as the first nailing. An additional cost of $12 to $18 per house might be expected.

Actual times involved in the cutting of bridging in the shop are shown in Table C, page 25.

System Costs (Exclusive of Bridging)

System costs, exclusive of bridging, in order of overall cost, lowest to highest, are given below:

System	Labor	Material	Total
#4	$28.35	$240.47	$268.82
#2	30.90	257.58	288.48
#3	45.02	281.30	326.32
#1	54.48	272.91	327.39
#6	56.89	279.16	336.05
#5	70.99	306.16	377.15

The above table makes clear the following conclusion:

The overall cost of systems employing 1/2" plywood subflooring over conventional joist floor framing was substantially lower than the other systems built.

The fact that the subfloor is the key to low cost can be further illustrated by combining the plywood subfloor with the four types of framing systems. Assuming the average cost of the plywood subfloor to be $128.00, the following costs result:

System - 1/2" plywood on	Subfloor	Framing	Total
2 x 10 joists 24" o.c. butted	$128.00	$141.89	$269.89
2 x 10 joists 24" o.c. lapped	128.00	147.04	275.04
2 x 8 joists 16" o.c. butted	128.00	159.57	287.57
2 x 8 joists 16" o.c. lapped	128.00	174.09	302.09

It can be seen that irrespective of the type of conventional joist framing, the plywood subfloor would result in the lowest cost floor system when 25/32" strip flooring is to be used as finish flooring.

If bridging is required, the costs of Systems #1 through #4 must be increased approximately $13.00. In this case the cost of System #6 becomes comparable to Systems #1 and #3; however, the plywood subfloor systems remain the least expensive of the five systems.

Modification of Component System Costs

The material and labor costs reported for System #5, the component system, do not give a true picture of the cost of the system due to the circumstances of the test. The following reductions give a more representative picture of the cost of the system.

1. The contractor required the use of 2 x 4 ledger strips on the beams, rather than the usual 1 x 2 strips. If 1 x 2 material could be used, the material saving would be 216 board feet and the cost reduction would amount to $27.00.
2. Since 4 x 10 material was not available, beams were built up by nailing two pieces of 2 x 10 together. If 4 x 10 material could be purchased, at least half of the nailing time could be eliminated. This would result in a saving of 192 minutes for a cost saving of $9.60.
3. Under normal circumstances the component system would be used for more than one house. If this were the case, the time required for preparing the jig for System #5 could be spread over several floors rather than be concentrated on one floor. If the jigging cost could be distributed over five houses, the jig preparation time would be reduced by 4/5 or 90 minutes. This would result in a cost reduction of $4.50.

The costs of the modified component system are shown as System #6 in the SUMMARY OF COSTS table on the following page.

Summary of Costs

The costs of modified component system (System #6) as well as the five test systems are summarized in the following table:

SUMMARY OF COSTS

	Shop Labor	Field Labor	Total Labor	Total Mtl.	Total
System #1					
Framing	$6.70	$15.48	$22.18	$151.91	$174.09
Subfloor		32.40	32.40	121.00	153.40
Subtotal	6.70	47.88	54.58	272.91	327.49
Bridging		7.52	7.52	5.22	12.74
Total	$6.70	$55.40	$62.10	$278.13	$340.23
System #2					
Framing	6.35	11.64	17.99	141.58	159.57
Subfloor	1.45	11.46	12.91	116.00	128.91
Subtotal	7.80	23.10	30.90	257.58	288.48
Bridging		5.16	5.16	5.22	10.38
Total	$7.80	$28.26	$36.06	$262.80	$298.86
System #3					
Framing	5.00	9.24	14.24	132.80	147.04
Subfloor		30.78	30.78	148.50	179.28
Subtotal	5.00	40.02	45.02	281.30	326.32
Bridging		8.88	8.88	5.22	14.10
Total	$5.00	$48.90	$53.90	$286.52	$340.42
System #4					
Framing	6.20	11.22	17.42	124.47	141.89
Subfloor	1.45	9.48	10.93	116.00	126.93
Subtotal	7.65	20.70	28.35	240.47	268.82
Bridging		9.36	9.36	5.22	14.58
Total	$7.65	$30.06	$37.71	$245.69	$283.40
System #5					
Beams	31.40	8.04	39.44	156.83	196.27
Panels	21.05	10.50	31.55	149.33	180.88
Total	$52.45	$18.54	$70.99	$306.16	$377.15
System #6*					
Beams	21.80	8.04	29.84	129.83	159.67
Panels	16.55	10.50	27.05	149.33	176.38
Total	$38.35	$18.54	$56.89	$279.16	$336.05

*Modified System #5. See explanation on previous page.

VI. COMPARISONS

Actual Labor vs. Estimated Labor

It is interesting to compare actual labor production with commonly used labor production rates.

	PRODUCTION RATE	
Item	Common	Actual
System #1		
Joists (2 x 8)	65 bm/hour	187 bm/hour
Subfloor (S4S diag.)	65 bm/hour	104 bm/hour
System #4		
Joist (2 x 10)	70 bm/hour	193 bm/hour
Subfloor (plywood)	100 sf /hour	292 sf /hour

Panel Fabrication and Erection Time

It is also useful to compare the fabrication times for the panels of System #6 with other experience. In a previous time study*, the panel fabrication and erection times are given as follows:

Fabricate panels (2052 sq. ft.)	14.7 min/100 sq. ft.
Erect panels	26.3 min/100 sq. ft.
Total	41.0 min/100 sq. ft.

When System #6 is expressed in the same form:

Fabricate panels (912 sq. ft.)	36.3 min/100 sq. ft.
Erect panels	19.2 min/100 sq. ft.
Total	55.5 min/100 sq. ft.

*Time Studies on a Component House, University of Illinois Small Homes Council-Building Research Council Research Report 60-2, page 12 (1960).

Labor vs. Material

In house construction it is generally assumed that labor costs are between 40% and 50% of the total costs. The table below indicates that this relationship does not hold for floor framing and subflooring.

LABOR COSTS VS. TOTAL COSTS

(Bridging eliminated)

System	Percentage Labor Costs
#1	16.6%
#2	10.7%
#3	13.8%
#4	10.5%
#5	18.8%
#6	16.9%